U.S. Department of Agriculture Agricultural Research Service

March 1993

Agricultural Research

New Solutions to Aquaculture Problems

Aquaculture—Netting Bigger Profits

For a "new" idea, fish farming has some surprisingly ancient roots.

Any complete list of "how-to" books on aquaculture would have to include "Fish Culture Classics," penned by Fen Li in China in 460 B.C. to describe his experiments in raising carp.

And Fen Li could be called a comparative newcomer to the field; the first written references to fish culture trace back to 1100 B.C., in the writings of Wen Fang from China's Honan Province. In Europe, the ancient Romans farmed fish and shellfish.

When fish culture finally made it to the New World, it proved to be a money-making venture. One early hatchery operator in Caledonia, New York, cleared a profit of $1,000 in 1865, 2 years after beginning his business; 3 years later, his profits had leapfrogged to $10,000.

Early fish culture in this country concentrated on species such as trout and carp for stocking. Today, market-ready catfish is king.

In 1990, U.S. catfish growers sold more than 360 million pounds of catfish to processors—a gain of 5 percent over the previous year, but perhaps still a letdown of sorts to those who had enjoyed double-digit increases in years past.

Some 166,000 acres nationwide are now submerged in catfish ponds, a total that does not include an estimated 13,000 acres of ponds under construction, being renovated, or currently out of production. Surveys have shown that many producers in the catfish industry are operating at less than full capacity and could quickly expand their operations.

Of course, catfish is only a part of the American aquaculture picture, albeit an important one. Trout is still a major aquatic commodity, and the field also includes crawfish, salmon, shrimp, bait fish, and even tropical fish.

Overall, the U.S. aquaculture industry has grown more than 15 percent annually in the past decade, booming from $200 million in 1980 to $860 million in 1990.

Per person consumption was about 16 pounds of fish and fish products from all sources in 1990. Experts predict this total will jump to 20 pounds by the year 2000 and to 25 pounds by 2010.

Why this growing consumer interest in fish? Fish is rich in protein and low in calories, a nutritional profile that appeals to consumers watching not only their waistlines, but also their intake of substances such as cholesterol and food additives. Fish is also a good source of calcium, phosphorus, potassium, and vitamin A.

A boom in fish farming could improve the health of the U.S. economy, too. The edible fish and shellfish trade deficit totaled $2.5 billion in 1990, as we imported $9 billion worth of fish products—an amount of imported nonmanufactured goods exceeded only by petroleum products.

Gains in fish farming not only help alleviate that trade imbalance, but also create demand for other U.S. farm goods, such as soybeans and corn. Fish farming offers new crop choices for farmers, as well as providing jobs for off-farm workers.

For example, in Mississippi, where 75 percent of domestic catfish production is based, the Delta region has seen the coming of three major catfish feed mills.

In addition, industry-support businesses have emerged that include hatcheries and nurseries, equipment manufacturers and suppliers, and providers of services such as custom harvesting, consulting, laboratory analysis, and hauling of live fish.

Catfish isn't the only success story in U.S. aquaculture. Trout exports are on the rise, valued at $2.1 million for the first half of 1991. And exports of ornamental fish were up 7 percent for the first half of the year.

And then there are crawfish. While much of the nation's crawfish are produced and consumed in Louisiana and adjacent states, crawfish production is actually one of the largest aquaculture industries in this country.

Crawfish "yields" per acre have not been particularly impressive—71 million pounds from 121,000 acres in Louisiana in 1990, compared with 67 million pounds of catfish from only 16,000 acres of ponds in Louisiana that same year.

But crawfish do offer some alluring advantages to the small family farmer: relatively low fixed costs of operation, natural reproduction of the "crop," and the ability to be double-cropped, or grown on the same acreage that at other times of the year sports golden heads of rice.

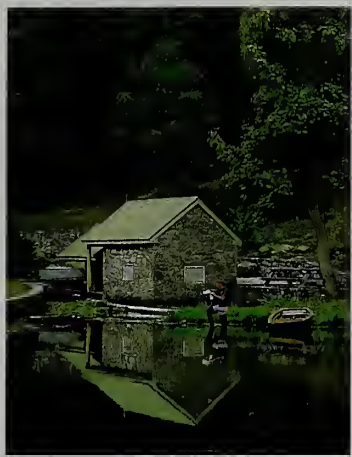
The U.S. Department of Agriculture is working to encourage aquaculture expansion through research and distribution of information on these new commodities. More than a dozen USDA agencies are involved either in research, marketing, or ensuring that consumers can count on an abundant and safe supply of fish products.

One such agency, the Cooperative State Research Service, administers funds to nonfederal agencies for aquaculture research.

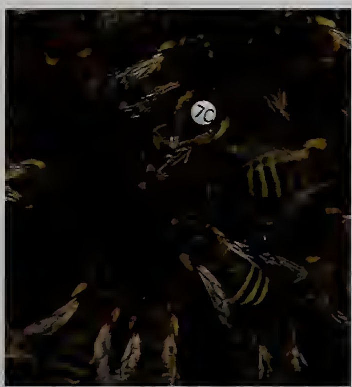
Another, the Agricultural Research Service, has aquaculture-related research under way at labs from Alabama and Louisiana to Oklahoma and Hawaii, tackling problems ranging from fish diseases to off-flavors in the finished product. This issue of *Agricultural Research* highlights a new trout research facility at Shepherdstown, West Virginia, that addresses the problem of aquaculture wastewater disposal.

Lewis W. Smith
Agricultural Research Service
National Program Leader
for Animal Nutrition and Aquaculture

Agricultural Research



Cover: Near the springhouse (circa 1775) at Morgan's Spring, West Virginia, system manager Joe Hankins collects water samples for chemical analysis. Eliminating the problem of water pollution and increasing fish yields are primary objectives of a continuing aquaculture research and demonstration project at this location supported by a grant from the U.S. Department of Agriculture. Photo by Scott Bauer. (K4246-12)



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Vol. 41, No. 3
March 1993

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Agricultural Research is published monthly by the Agricultural Research Service, U.S. Department of Agriculture, Washington, DC 20250-2350.

The Secretary of Agriculture has determined that publication of this periodical is necessary in the transaction of public business required by law.

Subscription requests should be placed with New Orders, Superintendent of Documents, P.O. Box 371954, Pittsburgh, PA 15250-7954. Please see back cover for order form.

This publication was printed with soybean oil-based inks.

When writing to request address changes or deletions, please include a recent address label.

Address magazine inquiries or comments to: The Editor, Information Staff, Room 408, 6303 Ivy Lane, Greenbelt, MD 20770

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Aquaculture Springs Up in West Virginia

Cool, clear water—an element essential to life. About 1,200 gallons a minute gush from a mountain spring just a little south of Shepherdstown, West Virginia. Located on the grounds of the Freshwater Institute, Morgan's Spring supplies the life source for new, experimental fish farming projects.

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Alicia Noble, a fish health specialist, examines trout specimens for disease before introducing them into the production system. (K4247-13)

"Our natural supplies of fish are at risk. Demand is increasing and ocean catch decreasing," says Lewis W. Smith. "We now import over 40 percent of all edible fish and shellfish products. One answer to lowering our imports yet still meeting consumers' demands is to step up our own efforts to produce more farm-raised fish."

ARS national program leader for animal nutrition, Smith also oversees agency involvement in aquaculture research.

For years, ARS has been involved in catfish research related to static water systems, either ponds or raceways. But this newest venture, begun at Morgan's Spring, is a step into uncharted territory for ARS—raising rainbow trout (and eventually other species) in recirculated, fresh spring water.

Researchers at the Freshwater Institute near Shepherdstown are raising rainbow trout two ways: in a large, high-tech, high-density, indoor tank system monitored by computers; and in a smaller, low-tech, simple, outdoor tank system run by gravity.

ARS scientists are evaluating the use of fish waste from the indoor tank system as fertilizer for high-value agricultural crops.

Although wastewater from fish farming isn't toxic to the environment, it can pollute streams by adding excess nutrients, like nitrogen, phosphorus, and organic matter.

"These nutrients increase algae's growth in water. Since the action of microbes decomposing the algae requires oxygen, this can lead to oxygen depletion, which can kill fish in affected waters," explains Paul Adler.

Adler is a horticulturist based at the ARS Appalachian Fruit Research Station in Kearneysville, West Virginia. He is working on a research project that would allow the aquaculture industry to expand without the risk of water pollution.

"To protect the environment, we've developed an economical and effective strategy to purify wastewater from the project at Shepherdstown," Adler says. "In nature, there is no waste. The byproducts of one organism are the inputs of another. We're just trying to emulate nature by engineering a system that doesn't generate waste."

To do so, he is using fruit, vegetable, and ornamental crops not only to clean the water, but also to provide a profit to growers.

"Of course, it'll cost money for growers to build greenhouses for these plants," Adler says. "However, conventional wastewater treatment technology is just as costly, and it lacks the benefit of bringing in additional income."

Another way Adler removes nutrients from wastewater is with periphytic algae. These algae are commonly seen as a green, slimy covering on underwater rocks in streams and lakes.

"These algae remove all the waste from water pumped from the rainbow trout tanks, allowing us to return wastewater to the stream in its original pristine condition," he says. And Adler is exploring yet another idea—constructed wetlands to treat the waste.

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This newest research venture is a step into uncharted territory for ARS—raising rainbow trout in recirculated, fresh spring water.

"Construction costs are only about 10 to 50 percent of those required for conventional waste treatment plants," he says.

Although an artificial wetland would not generate income by producing a high-value crop, it would reduce costs of treating the waste by conventional methods. Furthermore, it wouldn't require the horticultural expertise needed to maintain greenhouses. Another advantage of a wetland, Adler says, is that it creates a habitat for wildlife.

Native plants in a constructed wetland would take up excess nutrients from the fish wastewater. And the plants would do more than just absorb nutrients. According to Adler, they also secrete enzymes that can digest excess nutrients, making them absorbable by the water.

Engaging High-Tech Sophistication

The wastewater for Adler's research in greenhouses built at Shepherdstown comes from the high-density fish farming system installed there.

ARS cosponsors this research with the Freshwater Institute, founded by Robert E. Putz and now directed by Larry Selzer. The institute is part of the Conservation Fund, a nonprofit organization that works with private and public partners to protect and conserve land and water resources.

"Our high-tech recirculating system uses less water, controls the light that expands feeding time, and eliminates

Water quality in the 7,400-gallon recycled-water system must be monitored closely. Here, culture assistant Eric Leonard (right) and system manager Joe Hankins check levels of acidity and solids. (K4248-2)

predators," says John M. Heinen, scientific project leader. Subcontracted by the Freshwater Institute, Heinen works for Zeigler Brothers, a private aquaculture company headquartered in Pennsylvania.

"We harvest trout from this system about every 2 weeks. It takes about 200 to 220 days from stock to harvest," says Joseph Hankins, Freshwater Institute's director for aquaculture programs.

According to Hankins, in the first year of operation, success was phenomenal.

"Loss from fish mortality was very low. In fact, we harvested better than 95 percent of what we stocked," Hankins says. A second-year trial is now under way. Results so far look even better.

This Is Where It Happens

From a small room at the Institute, a sophisticated computer system monitors the entire project. Information from multistage oxygenators, microscreen particulate filters, and fluidized-bed biological filters constantly feeds into the computer that evaluates environmental conditions for the fish. These include waterflow, pH level, dissolved oxygen, and temperature.

Four identical fiberglass tanks, each holding 2,500 gallons of water, support several sizes of rainbow trout. Each tank holds about 5,000 fish—so many fish that the water looks murky and stays in constant motion.

But it's not just the movement of the fish that makes the water churn.

"Water enters through jet ports at the bottom of the tanks, which causes continual circulation in a crossflow fashion. This creates good velocity and maintains uniform water quality," Hankins explains.

Fish need lots of oxygen. "Through oxygenators, our system increases the dissolved oxygen levels two to three

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West Virginia aquaculturist Robert Huffman explains the setup for his spring-fed trout-raising system to neighboring farmers who are considering setting up their own systems. (K4983-17)

times above that of the water originally in the tank," Hankins says.

Because of the high density of fish and the water velocity, little fish waste settles in the tank. Instead, the water action propels it through outlets just above the tank bottom.

As water leaves the tank, it passes through a microscreen particulate filter that removes fecal matter. The water then flows into a biofilter where bacteria change the ammonia given off by the fish into nitrate, which is harmless to fish.

Since about 90 percent of the water in the tanks is recirculated, only 10 percent comes in directly from the spring. This keeps tank temperatures at about 55°F to 60°F.

"Since we have so many fish in the tanks, we need to strip from the water some of the excess carbon dioxide they generate," Hankins says. "The high alkalinity of spring water can combine with heavy fish loadings to raise free carbon dioxide to toxic levels. So we remove the excess simply by blowing air counter-current to the water."

As new water from the spring enters the tanks, some of the old water is removed and pumped up to the greenhouses for Adler's research on water quality. After cleaning, the water is returned to the stream.

Institute director Selzer talks about the risks involved with the high-tech system. "With so much depending on pumps, a power outage causes serious problems. If we had no backup equipment, we'd have only about 5 minutes to save the trout if this happened."

So there is an auxiliary system at the site. An emergency generator provides power to automatically bubble oxygen into the tanks if the dissolved oxygen falls too low. There's also an elaborate alarm system that summons help if the computer detects a problem.

But what about flavor? Does being raised in such an environment affect the way the trout taste? Apparently not.

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In Tucker County, West Virginia, extension agent Larry Campbell collects samples from a spring that supplies water to fish-production ponds. (K4981-13)

"We found the fish to be market quality. Our trained panelists are very sensitive to any bad flavor attributes in fish, and they found none in the trout from Shepherdstown," says Peter B. Johnsen who is in charge of the Food Flavor Quality Research Unit at ARS' Southern Regional Research Center in New Orleans.

Johnsen's research group also did a chemical analysis that showed the trout to be of acceptable quality. He says that the taste panel routinely evaluates fish from various aquaculture centers throughout the country.

Except for that used for research purposes, all the fish produced at Shepherdstown—nearly 15,000 pounds in 1991 and over 18,000 pounds in 1992—was donated to the West Virginia Department of Natural Resources to stock trout streams.

The Low-Tech Solution

The other end of the research spectrum at Shepherdstown incurs hardly any of the power-outage risks of the computer-managed system, yet produces healthy rainbow trout year round from a system that is practically maintenance free.

"We call it 'nature at work,'" says Charles E. Hicks, a research associate at the Institute. "No computers, no pumps, no fuss. In fact, once the equipment is in place, there's hardly any work required." He says this joint research with ARS, mandated by Congress, is in its third year. Its purpose is to evaluate the quality of the fish and demonstrate the feasibility of small aquaculture units for family farms in West Virginia.

"The first criterion is that the farm have a ground-fed spring, since the low-tech system operates on gravity," Hicks says.

At the Freshwater Institute, Morgan's Spring sends water through a 6-inch pipe into a small aboveground reservoir and on through 10 fiberglass tubs, situated in two rows of 5. Each tub is 5 feet in diameter and holds 360 gallons of water and about 750 trout of different sizes, to be harvested at different times.

"The free-flowing water makes the tubs practically self-cleaning. It also ensures that the temperature remains fairly constant," Hicks says.

Since water from natural springs often contains nitrogen, an exchanger in a water-conditioning box adds oxygen to the water and releases the nitrogen.

As with the more complicated system, a farmer using the gravity system can harvest trout year round. It takes about 15 minutes a day to make sure that water is flowing through the system and that fish are getting food from response feeders hanging above each tub. These devices release small amounts of food whenever fish jump up—searching for insects—and bump the mechanism. This way, food costs

are lessened, and water pollution from uneaten food is minimized.

According to Hicks, the entire low-tech system can be assembled in a barn, loaded on a trailer, and hauled with a pickup truck to selected sites.

"We now have 14 of these units—the complete research model—operating in rural areas of West Virginia," he says.

If this initial success continues, the system will be a model for 13 other Appalachian states. A farmer can have one of the units set up and operating for less than $10,000.

Marketing is the real concern now. County extension agents are working closely with researchers and farmers to find a market niche. Thus far, a new prison in the vicinity has promised to buy trout raised in Summers and Fayette Counties.

But West Virginia farmer Robert Huffman doesn't have to worry about marketing his trout. From March to Labor Day, he says there's a steady stream of fishermen beating a path to both the ponds that he keeps fully stocked with beautiful mountain trout.

"Visitors pay $2 each to fish, and 20 cents per inch for the trout they catch. Most people take home more than enough for supper," he says.

Tucker County extension agent Larry Campbell encouraged Huffman to try the spring-fed trout-raising system. The mountain spring on Huffman's property supplies water for seven private homes in addition to the 4,500 trout in his project.

Huffman's 100-acre farm backs up to Black Water Falls State Park and is only a few miles from Canaan Valley State Park.

"An awful lot of my business comes from the tourists who visit the parks. They hear about the trout by word of mouth and come on out to fish," he explains.

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After inspecting the growth of trout in these 150-gallon fiberglass tanks, Joe Hankins transfers the larger ones to separate tanks. (K4247-5)

Although the spring-fed system has been operational on his farm for just a little over a year, Huffman says he has already recovered his initial startup expenses. And this success was in spite of a near disaster that occurred only a few months after the system was installed.

"One night, a red lizard about the size of my thumb fell into the water and got tangled up in the gate valve, stopping the waterflow. Before morning, I had lost about 1,700 trout. I broke even with the trout raising anyway, but look forward to maybe making a profit next year," he says.

Retired from the West Virginia State Highway System, Huffman also raises cattle and hay to supplement his pension.

Other collaborators in this research include the West Virginia University Extension Service, and the West Virginia Departments of Agriculture and Natural Resources.—By **Doris Stanley,** ARS.

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Additional information about U.S. aquaculture is available from USDA's National Agricultural Library. The Aquaculture Information Center gathers, computerizes, maintains, and updates data on all aspects of the aquaculture industry. Contact the National Agricultural Library, Aquaculture Information Center, 10301 Baltimore Ave., Beltsville, MD 20705-2351. Phone (301) 504-5558, fax number (301) 504-6409.

Fat, Lean, and the Role of Diet

A calorie is a calorie is a calorie—right?

Not when you're feeding beef cattle, says Robert H. Gallavan, a research animal physiologist in the ARS Grazinglands Research Unit at El Reno, Oklahoma.

In studies begun at El Reno in 1989, Gallavan and animal nutritionist Samuel W. Coleman compared fat deposits and meat characteristics of Angus steers eating either primarily forage or grain.

For 32 of the steers, 90 percent of "dinner" was a sorghum silage/alfalfa hay mixture, with the other 10 percent provided by corn and soybean meal.

Another 32 steers consumed 87 percent of their diet in the form of a mixture of corn, soybean meal, and cottonseed hulls.

For 145 days, the net energy intake—the energy from the diet available for meat and fat production—was similar in the two groups, Gallavan says. "In both cases, we were striving for a fairly productive diet commonly used among livestock producers."

The animals on concentrate diet gained 1.7 pounds per day, while those on forage diets gained 1.3 pounds per day. But the difference was primarily due to the low dry matter content of the sorghum silage during one 4-week period early in the trial.

After 145 days, all the animals were switched to a standard "finishing diet" of corn, soybean meal, and alfalfa hay and allowed to eat all they wanted of that mixture. At regular intervals, animals from each of the initial diet groups were slaughtered and their carcasses carefully inspected.

While the animals' overall weight gains were not that different, their carcasses did show some differences ranging from size and quantity of fat cells to total amount of carcass fat.

"For example, the animals on forage diets produced leaner meat, but the meat was tougher," Gallavan reports.

When a beef animal—a ruminant—eats, microbes in its rumen or stomach break down carbohydrates in the feed into substances called volatile fatty acids, such as acetate and proprionate.

"Proportions of the various volatile fatty acids produced in the rumen differ between a diet of forage and one of grain," notes Gallavan. "So although the net energy intake may be the same for two diets, how the animal converts the feed could be quite different."

The volatile fatty acids catch a ride in the bloodstream to the liver. The liver then processes proprionate into glucose as needed. The remaining volatile fatty acids may be converted to fat or used by cells for energy.

The ratio of proprionate to acetate from a particular diet may be important, because some researchers believe proprionate is easier for the

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Angus cattle on pasture. (K4148-10)

liver to convert to glucose for the needed energy.

"The enzymes that make glucose have to work with a three-carbon unit," explains Gallavan. "Proprionate is three carbons, but acetate is only two carbons."

After 45 days on the finishing diet, all of the Angus looked evenly matched—regardless of their early diet—as far as the amount of subcutaneous fat just below the surface of the animals' skin, the degree of marbling (fat interwoven with the muscle), and quality grade of the carcass.

Even so, Gallavan says, the meat from the animals that began on the concentrate diet was consistently more tender than meat from the forage-fed animals, although the differences were very small.

If fat from storage sites inside the body, such as the gut, is any indication, forage-fed steers appear to store their fat in a large number of relatively small cells. By contrast, the concentrate-fed steers have a smaller number of larger fat cells, Gallavan notes.

Differences in how animals ultimately store fat could be linked not only to what they ate, but also to how they ate it, Gallavan adds.

When an animal gobbles down much of its daily diet at one sitting—as might be the case with feed concentrate—the result is a rush of available nutrients. The cells of the body will use what they need for energy and growth, but the overabundance results in "leftovers" that are stored as fat.

"Under certain conditions, it may be more efficient to feed the animal more frequently in smaller amounts," says Gallavan. "For one thing, it has been shown that rumen bacteria waste less of the feed that way by converting it to methane, a waste product that the animal cannot use."

In comparison to feed concentrate, the less digestible forage leaves grazing animals feeling "full" more often. For that reason, they tend to eat a while, pause and ruminate for a while, then eat some more—a pattern that is generally less conducive to production of fat.

The greater bulk of a forage diet has led to conjecture that the gastrointestinal tract of an animal on a forage diet might be physically larger. This, in turn, could put the animal at a disadvantage in the feedlot, Gallavan says.

When an animal gobbles down much of its daily diet at one sitting—as might be the case with feed concentrate—the result is a rush of available nutrients. The cells of the body will use what they need for energy and growth, but the overabundance results in "leftovers" that are stored as fat.

"The GI tract consumes as much as 40 percent of total energy expenditures for the body, because the cells of the GI tract are constantly turning over—being replaced by new cells," he explains.

"This would mean an animal with a large GI tract would have to eat more to gain as much weight as an animal with a smaller GI tract.

"But on the two diets we used in our studies, we saw no difference in gut size between the animal on silage versus the animal on grain. So we wouldn't expect to see that particular disadvantage to the forage animal in the feedlot."

One similarity between animals in the feedlot: Whether an animal spent its early days on forage or feed concentrate, it's likely to pack on more fat as a percentage of total body weight for every day it dines on the finishing diet dished up at the feedlot, Gallavan notes.

"In our study, regardless of what the animals started out eating, when we slaughtered them after 45 days on the finishing diet, 75 percent of them graded 'Choice,' and 21 percent of the meat by weight was fat," he says.

"After another 30 days on the finishing diet, when we slaughtered a second group, again 75 percent of those animals graded 'Choice'—but by then the fat portion of the meat had risen to 28 percent.

"The question always comes up: How long can an animal be on the finishing diet before it starts losing feed efficiency?" Gallavan says.

"Normally, producers may think of feed efficiency simply in terms of the amount of feed required to increase body weight. We need to start thinking in terms of the amount of lean meat the animal is gaining from that feed."—By **Sandy Miller Hays**, ARS.

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Meat Tenderness Enhanced With Calcium Process

Most everyone enjoys sinking their teeth into a nice, thick, juicy steak. But no one really knows if a cut of meat is going to be tender until they take that first bite.

"A major problem facing the beef industry today is the various degrees of tenderness found in retail cuts of meat," says Mohammad Koohmaraie, an animal physiologist at the Roman L. Hruska U.S. Meat Animal Research Center, Clay Center, Nebraska. Koohmaraie is also head of the Meats Research Unit.

To improve meat tenderness, carcasses or cuts are usually stored (aged) under refrigeration for 7 to 14 days. Now Koohmaraie has found a way to achieve that same degree of tenderness in just 24 hours.

His research has been instrumental in proving the role of calcium-dependent proteases, or calpains, in the tenderization process.

"Injecting a carcass with calcium chloride 'turns on' the calpains, which cause muscle degradation, or aging, of meat and speeds the process," says Koohmaraie.

A major problem facing the beef industry today is the varying degrees of tenderness found in retail cuts of meat.

When carcasses are refrigerated for aging, the small amount of calcium naturally present in the meat builds up, activates the calpains, and tenderizes the meat.

Injecting the carcass immediately, or up to 24 hours after slaughter, boosts the muscle calcium concentration and yields tender meat in just 1 day. Over-tenderization is not a problem because the calpains break down while the muscle is degrading.

Notes Koohmaraie, "At 24 hours post mortem, the process will not interfere with grading and inspection. This will make it easier for the meat industry to adopt this technology."

Sensory panel evaluations show that the flavor of the meat is not affected by the injections.

This technology may allow breeders to take advantage of the desirable traits in *Bos indicus* cattle, like Brahman, without concern for tenderness of the breed's meat. The calcium injection method is also effective with lamb.

And extra calcium in the meat may allow it to be sold as fortified, giving consumers an alternative source of calcium.

Calcium chloride is already approved as a food additive. —By **Marcie Gerrietts,** ARS.

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◀ **Animal physiologist Mohammad Koohmaraie, assisted by biological technician Kathy Mihm, injects calcium chloride solution into a cut of beef. The treatment yields tender meat in just 24 hours and could eliminate the need for refrigerated aging of 7 to 14 days. (K4937-18)**

▶ **In studies intended to improve meat tenderness, Koohmaraie separates meat muscle proteins. (K4942-14)**

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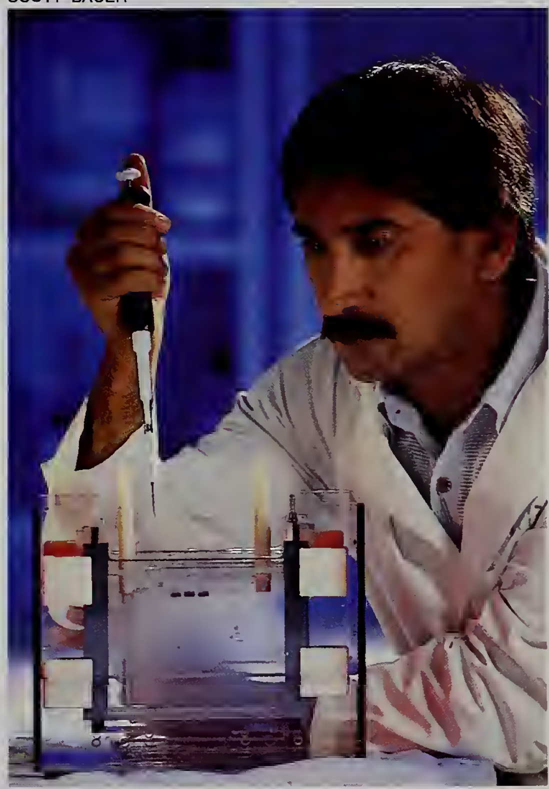
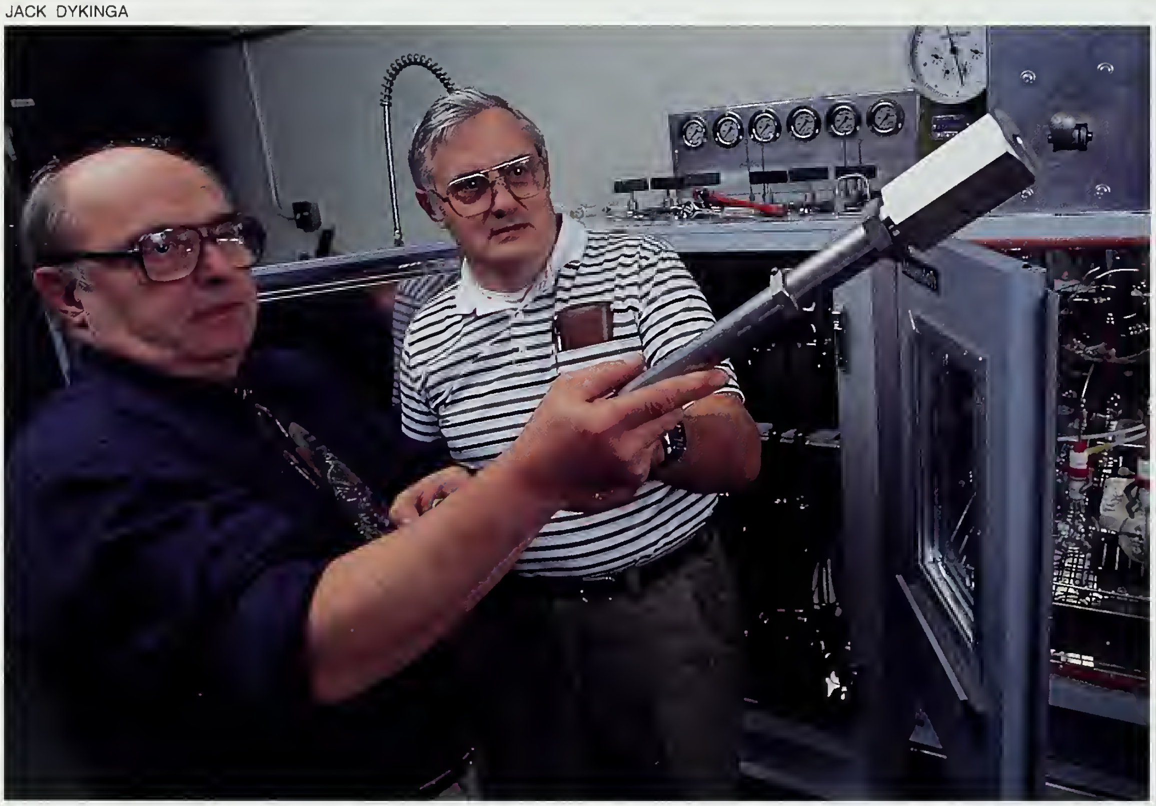


Cutting Use of Laboratory Solvents

Supercritical fluid extraction may never be a household word, but federal researchers are hearing good things about it.

This process, known by the acronym SFE, provides a cost-effective way to help obtain information on trace levels of toxicants in foods without the use of chemical solvents. It may be important in helping federal regulatory agencies comply with U.S. Environmental Protection Agency (EPA) rules.

JACK DYKINGA



Jim Johnson (right) shows FSIS chemist Donald Goodspeed how to install the extraction cell containing meat samples into the SFE unit. (K4859-5)

Recently, as part of a pollution-prevention strategy, EPA mandated that all federal agencies cut back on solvents used in laboratory procedures. It has called for a 50-percent reduction in the use of 17 target chemicals in all federally owned and contractor-operated laboratories by 1995. All other federal facilities must reduce by one-third the use of these chemicals by 1995.

ARS' NCAUR (National Center for Agricultural Utilization Research) in Peoria has become a leader in SFE technology. Companies from all over the world have visited the center to learn about the process.

NCAUR chemist Jerry W. King has enabled many federal agencies to gain access to SFE, including USDA's Food Safety and Inspection Service (FSIS) and Federal Grain Inspection Service (FGIS), and the Food and Drug Administration (FDA).

SFE isn't new. Food processors have been using it to decaffeinate coffee, extract hops for flavoring beer, and perform other food-processing tasks.

The SFE technique uses gases, such as carbon dioxide (CO_2) or nitrous oxide, heated and compressed to high densities to the point that they resemble liquids. Carbon dioxide has been the gas preferred by most researchers engaged in supercritical extraction, says King.

SFE uses CO_2 kept at an intermediate state between gas and liquid, at selected pressures and temperatures, to extract target substances from food samples—with no harmful effects to the food.

And NCAUR researchers have proven that SFE can be used to replace specific steps in the soybean oil refining process, thus eliminating the need for processing chemicals that the industry finds difficult to dispose of.

King and co-researchers at the Peoria center have adapted and refined equipment to make SFE safer and less expensive than standard tests for monitoring pesticide residues in fatty foods, like meats, and in nonfat foods, such as produce.

"In low-fat foods, the use of chemical solvents hasn't been very effective," says Richard Ellis, Director of the FSIS Chemistry Division in Washington, D.C. FSIS is responsible for checking fresh and processed meat and poultry products to ensure that they are safe and wholesome.

Although the United States has banned the use of DDT, for example, other countries may not have restricted the use of chlorinated pesticides, which don't easily degrade and may persist in the environment.

In several collaborative studies with other agencies, King has used SFE to analyze the pesticide content of a variety of foods. With FDA and FGIS, he has examined nonfat foods such as carrots, wheat, lettuce, and spinach. For FSIS, he has extracted fat from meat products, such as frankfurters and hamburger. The fat-removal process is important in meats because pesticides tend to concentrate in the fatty tissue.

Based on these tests, King says SFE yields accurate analyses comparable to those obtained by standard analytical methods using chemical solvents.

Several other factors make SFE worth considering as an alternative to

standard analytical methods currently used by these regulatory agencies. It's safer for laboratory workers, and CO_2 won't harm the environment.

SFE is also potentially less expensive than standard analytical methods that rely on chemical solvents to extract pesticides and drugs from food products.

Marvin Hopper of FDA's Total Diet Research Center in Kansas City, Missouri, says, "SFE reduces the cost of both purchasing chemical solvents and disposing of them. It costs about $3 per sample to analyze nonfatty foods, such as vegetables, with chemical solvents. SFE can do the job for 75 cents per sample.

"The cost of analyzing a fatty food with chemical solvents is about $1.50—double an SFE-processed sample," adds Hopper.

It also saves time. Chemical extractions using ether or hexane as solvents can take from 3 to 5 hours. With SFE, lab technicians obtain similar results in about 60 minutes.

ARS engineering technician Jim Johnson has built a multisample instrument that can process six samples simultaneously. His version is based on earlier units developed by King and Hopper.

Johnson installed the six-sample unit at the FSIS laboratory in Alameda, California, in September 1992 and showed FSIS personnel how to prepare samples and operate the unit.

An SFE device is also used in FDA's Total Diet Study, which is regarded as a reference in setting regulatory tolerances and in monitoring pesticides in the food supply. The FDA laboratory in Kansas City periodically measures levels of pesticide residues in 234 common table-ready foods.

"In the future, SFE may also be able to provide further detailed analytical studies on food samples. That would be helpful in determining the precise nutritional composition of foods, to comply with new FDA food-labeling requirements," says King.

King's original multisample SFE unit was studied and improved on in 1989 by Lee Scientific, a division of Dionex Corporation, located in Salt Lake City, Utah. The firm has since marketed a miniaturized model.

Meanwhile, FSIS plans to use an SFE multisampler to check low-fat imported meat products for pesticides. Ellis of FSIS' chemistry division says, "We've targeted for elimination five chemicals—chloroform, dichloromethane, mercury, toluene, and xylene—that we routinely use in our laboratories for food composition, residue analysis, and the study of diseased tissue."

He says that FDA tolerances for many chlorinated hydrocarbon pesticides are between 100 to 300 parts per billion. Analytical methods used by FSIS now detect residues as low as 10 to 20 parts per billion.

Although FSIS currently recycles solvents to reduce the cost of purchasing new reagents, they hope to convert to supercritical fluid extraction to help alleviate the impact of their current testing protocols on the environment.—By **Linda Cooke,** ARS.

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JACK DYKINGA

At a FSIS laboratory in Alameda, California, chemist Carolyn Nettles removes a flask of extracted fat from an ARS-developed supercritical fluid extraction unit. (K4860-11)

Varroa jacobsoni **mites on the backs of bees (brown bumps). Young mites develop in the bees' brood cells and suck the blood of both pupae and adults. (K5069-21)**

LILIA DE GUZMAN

Fighting for Survival Against Bee Mites

Chemical Controls Keeping Beekeepers Afloat

Everything seemed fine last summer when Jerry Stroope prepared to extract honey from his 4,400 bee colonies in Texas.

But as his employees began examining the hives, they found that some colonies had been wiped out completely—and that in others, there were only a handful of bees left, covered with deadly mites.

Stroope said he lost from 25 to 50 percent of his colonies to a mite called varroa, which he's now controlling with a chemical called fluvalinate. Without it and other miticides, he says, "we'd be out of business."

Stroope's experience has become a familiar one for honey producers since the mid-1980's, when varroa and a second pest, the tracheal mite, were discovered in the United States.

The tracheal mite, *Acarapis woodi*, was first found in Texas in 1984 and has now infested bee colonies throughout the country. The mite lives, feeds, and reproduces inside the bee's breathing tubes, blocking oxygen flow and eventually killing the bee, says William T. Wilson, an entomologist with USDA's Agricultural Research Service in Weslaco, Texas. He estimates that 50,000 or more honey bee colonies have been lost each year since 1988 because of the tracheal mite.

The varroa mite, *Varroa jacobsoni*, was discovered in Florida and Wisconsin in 1987, according to Hachiro Shimanuki, who is in charge of the ARS Bee Research Laboratory in Beltsville, Maryland.

Varroa attacks both adult bees and larvae. Young mites developing in the brood cells suck the blood of bee pupae.

As Stroope discovered, a serious infestation of varroa mites can destroy a bee colony quickly. And with few visual warnings, Shimanuki says.

The mite problems couldn't have come at a worse time for the beekeeping industry. Not only have producers been fighting an ongoing battle against bee diseases, but in recent years China has stepped up its exports of less-expensive honey into the United States—undercutting prices of domestically produced honey.

Added to these problems, the mites are a one-two punch that floored some producers and knocked others out of business altogether.

Those who survived are controlling the mites with several chemicals, say Shimanuki and Wilson, who led research teams that studied the chemicals and helped gain Environmental Protection Agency (EPA) approval for their use. "Without these chemicals for controlling mites, I think we'd be finished," says Richard Adee, who's been raising bees since 1957.

Adee, president of the American Honey Producers Association, has about 45,000 bee colonies from the Dakotas to Mississippi, making him the nation's largest commercial beekeeper.

With a peak of about 50,000 bees per colony, Adee looks after more than 2 billion "employees." Without chemical controls, Adee says, he'd lose one-third of his bees to tracheal mites and 20 to 30 percent to varroa each year. "The beekeepers who are surviving are using chemicals and are using them preventively," he says. "Mites will continue to be their number-one problem."

To control them, ARS researchers have been working with private companies and beekeepers such as Stroope and Adee to register four compounds against varroa and tracheal mites.

ARS' research role has been to study the efficacy, residues, and toxicity of the mite controls, Wilson explains. "ARS researchers are making sure the chemicals really work against the mites and that they don't harm the bees or leave unwanted residues in the honey," Wilson says.

Before these chemicals were approved by EPA, the only way to stop the spread of the mites was to destroy infested beehives—a costly practice.

SCOTT BAUER

Biological technician Gary Delatte and graduate student Lilia de Guzman examine a colony of mite-resistant bees whose ancestors were brought for study to the United States from Yugoslavia in 1989. (K5064-2)

Three of the four chemical compounds have thus far gained EPA approval. They are:

- Menthol. Registered in 1988 for use against tracheal mites, this natural substance, often used in cough drops and other products, kills mites without harming the bees. Since it has to vaporize to be effective, it must be used at temperatures of at least 60°F—limiting its use in northern states. "But it has helped considerably against tracheal mites," Shimanuki says. "About 50 tons of menthol a year, on average, were used in beekeeping operations nationwide in the late 1980's."
- Amitraz. Last November, EPA approved this compound under the trade name Miticure, which can be used in northern states and other areas where beekeepers need an alternative to menthol. Amitraz is widely used against a variety of insects, and is impregnated in plastic strips—like a cat flea collar—that are placed inside the hive. When bees walk over the strips, amitraz rubs off on them and kills both mite species without harming the bees.
- Fluvalinate. Approved for general use against varroa mites in 1988, fluvalinate is a synthetic pyrethroid that's used against beetles, moths, and other insects. Like amitraz, it's also impregnated in plastic strips that are placed in the hive.

Shimanuki and Wilson note that all these chemicals should be used in the spring or fall—before or after the main period in which bees gather nectar. Otherwise, chemical residues could wind up in marketable honey.

EPA approval is still pending for a fourth chemical, formic acid. In preliminary studies, Wilson says, it appears effective against both tracheal and varroa mites and is less expensive than the chemicals already approved for use. "It costs about 50 cents per colony to treat with formic acid, compared to $2.50 or $3 for the other chemicals," Wilson says, adding that further studies are needed to determine if formic acid residues could be spread to honey.

Beekeepers say holding down control costs is critical to their businesses.

Adee estimates that mite controls cost him about $135,000 per year. Horace Bell, who operates about 40,000 colonies based in Florida, says treating for mites is a "Catch-22" situation. Using the chemicals raises the cost of the honey, making it more

expensive than imported honey. But not treating for mites means certain loss.

"If you don't treat, you're dead; and if you do, you're still dead," Bell says. "We seem to have a handle on how to control them. It's just a matter of the cost of doing it."

The mite problems are even more serious because of the crop-pollinating value of honey bees to U.S. agriculture.

USDA estimates there are 3.2 million bee colonies in the United States (a figure that includes only beekeepers with five or more colonies). In 1991, about 220 million pounds of honey worth about $124 million were produced in the United States.

While honey itself is an important bee product, pollination services measure in the billions of dollars.

For fertilization to occur, pollen—the male sperm in plants—has to be spread from plant to plant. This cross-pollination occurs mainly through wind and insects.

Among insects, bees are the most efficient and dependable pollinators known. As they search for nectar and pollen, they spread the pollen among plants without damaging them.

LILIA DE GUZMAN

This micrograph shows bee trachea infested with mites. Unchecked, these parasites live, feed, and reproduce inside the breathing tubes, blocking oxygen flow and eventually killing their host. Magnification is about 200 times. (K-5069-23)

Economic estimates vary on the value of honey bees as pollinators. A 1992 study by researchers at the State University of New York (SUNY) at Buffalo and Brockport estimated that they are worth between $1.6 and $5.7 billion a year to U.S. agriculture. Other studies place the figure even higher.

USDA estimates that U.S. farmers rent about 1 million bee colonies each year to pollinate a variety of crops such as almonds, apples, alfalfa, apricots, oranges, grapefruits, melons, cucumbers, asparagus, and broccoli.

About 400 agricultural crops worldwide—including 130 in the United States—are pollinated, at least partly, by honey bees, according to the SUNY study.

While the chemicals have given beekeepers a way to control mites, Adee

Breeding Bees for Mite Resistance

Within the next year, ARS will step up its efforts to fight honey bee mites by releasing bees resistant to the pests.

This spring, the agency is releasing a new honey bee stock from Yugoslavia that has resistance to both tracheal and varroa mites. ARS researchers are also evaluating another stock, from England, called Buckfast, for resistance to tracheal mites and could release resistant bees in late 1993 or early 1994.

While it's common for USDA to release new plant varieties, the Yugoslavian bees are the first honey bees the department has ever released for breeding, according to Ralph Bram, the agency's national program leader for medical and veterinary entomology.

"Insect varieties have genetic traits that can benefit agriculture in the same way that different plant varieties have helped create crops with disease and insect resistance and other improvements," Bram says. "Releasing new bee varieties underscores how seriously we view the mites and how committed we are to helping the beekeeping industry solve the mite problem."

ARS and cooperating scientists have been studying the Yugoslavian bees since 1984. The project, initiated to find resistance to varroa, began 3 years before the mite was discovered in the United States.

But researchers found there was an added bonus: The Yugoslavian bees were also resistant to tracheal mites, according to geneticist Thomas Rinderer, who is in charge of the Honey Bee Breeding, Genetics, and Physiology Research Laboratory in Baton Rouge, Louisiana.

The Yugoslavian bees were brought to the United States in July 1989. They were observed for 6 months in a quarantine apiary on Grand Terre Island off the Louisiana coast to make sure the bees had no dangerous diseases or parasites that could spread to American honey bees. Once they were found to be safe, the bees were moved to the Baton Rouge lab.

Field tests began in 1990, to see if the Yugoslavian bees had more varroa mite resistance than U.S. honey bees. Rinderer says that the Yugoslavian bees are about twice as resistant to varroa mites as susceptible U.S. varieties. "As far as tracheal mites, they're not immune, but they are so resistant that beekeepers wouldn't have to treat their colonies for tracheal mites—just for varroa," Rinderer says.

and others worry that the mites will eventually develop resistance to them.

So ARS researchers are studying natural compounds to control the mites. Shimanuki, along with ARS entomologists Nicholas Calderone and William Bruce at Beltsville and University of Maryland researcher Gordon Allen-Wardell, have found naturally occurring compounds that kill tracheal mites. In preliminary lab studies, the most potent have been clove oil and citronellal, which is derived from sources such as lemons and lemon grass and is the active ingredient in the citronella candles common around summer picnic tables.

Clove oil killed 78 percent of mites tested, while citronellal killed 68 percent. "These numbers are promising, because we don't have to kill all the mites to obtain effective control," Calderone says. Field studies of clove oil and citronellal and other potential natural controls of tracheal mites are scheduled for 1993.

SCOTT BAUER

Varroa jacobsoni **mites invade bee colony brood cells and suck the blood of developing pupae. (K5069-20)**

"We need to have as many weapons in our arsenal as we can against tracheal and varroa mites," Shimanuki says. "They're so threatening that we can't take any chances."—By **Sean Adams,** ARS.

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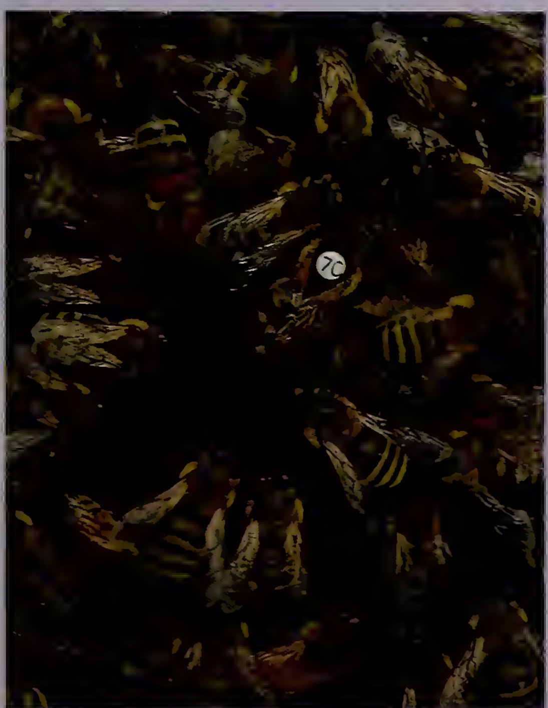
"For a beekeeper, to save $2 per colony in menthol treatments for tracheal mites is important."

Researchers at Baton Rouge also got good results from a 1991-92 study of the Buckfast bees, which Bram brought into the United States in 1990. The bees are named after the famous Buckfast Abbey, where Brother Adam, a 94-year-old monk, spent about 70 years breeding the bees.



Yugoslavian queen (marked) and worker bees. (K-5069-22)

After 6 months in quarantine, the Buckfast bees and several other varieties were evaluated in four states for resistance to tracheal mites, honey production, and other characteristics, according to Robert Danka, an entomologist at the Baton Rouge lab. He said the study's results confirmed earlier reports: Fewer than 10 percent of the Buckfast bees were infested with tracheal mites, compared to up to 80 percent for susceptible bees. Yugoslavian bees also had low infestation levels in the tests.

Danka says that further studies are being done before determining a date for offering breeders stock that incorporates the Buckfast resistance traits. He said the agency's agreement with the abbey prohibits releasing pure Buckfast bees in this country.

Last summer, ARS established a stock release panel that will select specific breeders to increase and maintain supplies of Yugoslavian bees and Buckfast crosses once they're released, says Rinderer. The panel consists of a chairman from ARS and representatives from four industry associations.—By **Sean Adams,** ARS.

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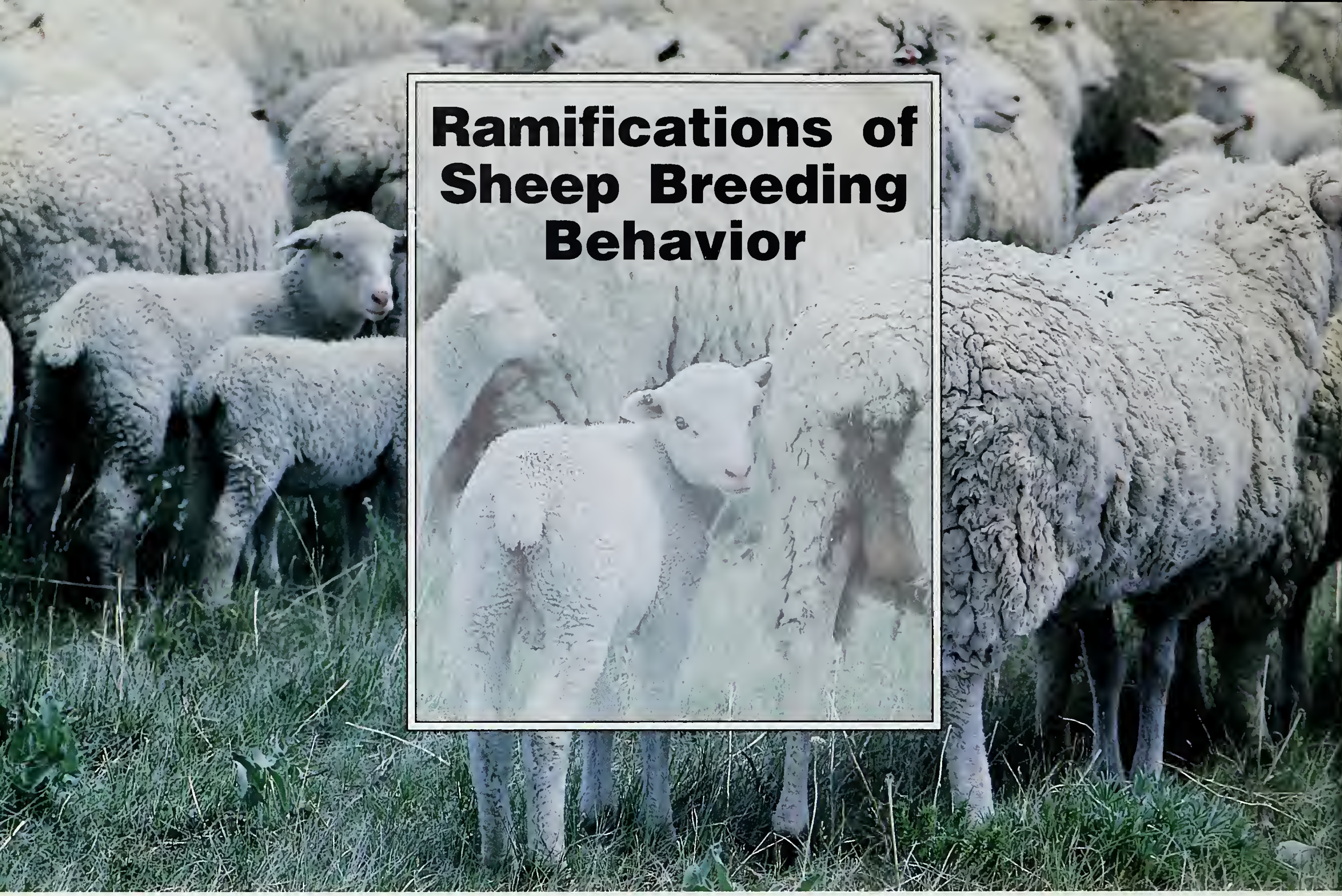

Ramifications of Sheep Breeding Behavior

(K2681-15)

The highs and lows of sexual activity of rams at the U.S. Sheep Experiment Station in eastern Idaho have captured the attention of scientists who want to make American sheep ranching more profitable.

"Our reason for studying the sexual behavior of sheep," says ARS animal scientist James A. Fitzgerald, "is simple economics. But this research may also help answer some fundamental questions about the biology of sex."

Fitzgerald heads the ARS Range Sheep Production Efficiency Research Unit that is part of the 77-year-old station near Dubois.

Nearby and in neighboring states, shepherds tend flocks on vast ranges and mountain pastures. To stay in business, ranchers need to produce as many healthy, hardy lambs as possible each year. That lamb "crop," as it's called, hinges partly on the performance of the rams in the flocks. Ideally, each ram mates with 50 to 100 ewes every fall.

But what if that ram turns out to be a shy breeder? The rancher may end up getting fleeced for anywhere between $300 and $500, the usual purchase price of a breeding ram. And feed and care for that animal runs between $50 and $100 a year.

In the short term, there's the risk of fewer lambs that season. And if that low-performance trait is inherited, there's a long-term threat of spreading it within the flock.

Artificial insemination, or AI, sidesteps the problem of the male's variable libido. AI is commonplace in both the dairy cattle and turkey industries. But, because of the labor involved, most range and farm flocks of sheep still make lambs the old-fashioned way.

Nonetheless, about 15 percent of the rams in this country may ignore a ewe's mating overtures, according to observations by Fitzgerald and colleagues.

Uncovering the basis for this behavior is interesting from both a practical and a scientific standpoint. More knowledge will shed light on better ways to select the best rams to use, Fitzgerald says.

"As it is now, rams are selected mainly by how quickly they grow—the faster and bigger, the better," says Fitzgerald.

"We think other factors are at least as important."

Anne Perkins, an assistant professor of psychology at Carroll College in Helena, Montana, has worked closely with Fitzgerald for the past 5 years. Their findings lend credence to the argument that rams uninterested in mating with ewes are that way from birth.

In fact, the unborn ram's experience in the womb may shape his sexual performance when he is mature.

Male lambs born alone were less likely to be interested in breeding ewes than those born in multiple births. And rams born with a male twin were more likely to be highly sexed than those who shared the womb with a sister.

This womb-mate effect reinforces earlier findings in rats and gerbils by other researchers, who found that males flanked by males tended to mate sooner and more frequently. A possible explanation: differences in the powerful chemical hormone messengers that bathe the growing embryos.

Hormones dictate a host of changes within the body, from heart rate to sexual fate. "We think that the additional testosterone present when two males share the womb could play a role in why such rams have a higher sex drive," says Fitzgerald.

He's testing that notion in a new study of pregnant ewes begun last fall. He injected the ewes with testosterone, which traveled through the placenta into the lambs growing inside the womb. Male offspring born to those ewes will be observed when they mature, to see whether the extra hormone affects their sexual behavior.

Such observations, called serving-capacity tests, consist of 30-minute sessions during which a technician records the behavior of a ram placed in a pen with four ewes in heat.

Six years ago, the team showed that about half of the low performers are male oriented; that is, they consistently mount males even when females in heat are present.

Homosexual rams and heterosexual rams that are lazy breeders cause ranchers a similar problem: fewer lambs (or none at all!). But the causes of their different behaviors are harder to pin down, says Perkins. Still, several studies offer some interesting clues.

She and Fitzgerald found they could alter performance among the heterosexual rams, using compounds that either mimic or block the effects of opiates. Produced in the brain, natural opiates are chemicals that affect sensations of both pleasure and pain.

Injecting rams with one type of synthetic opiate, the pain killer morphine, enhanced their natural opiate levels and made those rams less interested in sex.

The opposite was also true. When low-performing rams were injected with naloxone, a chemical that blocks natural opiates, they became better performers.

"We looked at opiates because we know brain opiate levels fluctuate with the seasons, as does libido," says Perkins. "We speculated that perhaps the natural opiate levels of low performers were elevated year round. If that were true, these rams would be perpetually 'out of season.'"

Additional studies are needed to confirm these preliminary results.

The unborn ram's experience in the womb may shape his sexual performance when he is mature.

MICHAEL THOMPSON

(K5086-1)

Homosexual rams weren't affected by either of the drugs—which suggests that opiates play a role in performance, but not preference.

In another study in collaboration with the University of Wyoming, Perkins and Fitzgerald found differences in certain brain cells called hormone receptors between low- and high-performing rams.

Receptors are specialized cells that perceive information carried by hormones in the bloodstream. One, called the estradiol receptor, responds to the hormone estrogen. Although estrogen is commonly known as a female hormone since it's involved with ovulation, it's also critical in males. Testosterone produced by the testes is converted into estrogen in the male brain, where it promotes male sexual behavior.

Rams with higher libidos had nearly twice as many estradiol receptors in their brains, compared to the lazy breeders, the scientists discovered.

"But," says Fitzgerald, "we still don't know whether rams are born with these receptor differences, or whether they acquire them as they grow up."

Although their studies suggest a biological basis for differences in sexual behavior, the scientists agree that environmental influences can't be denied.

"There are probably critical periods during gestation and during a ram's upbringing that can alter his sexuality," says Perkins.

In fact, rams who grew up solely in the company of other rams exhibited less interest in mating, compared to those that spent short time periods near ewes in heat during their first year of life, according to a recent study by Edward O. Price, an animal scientist at the University of California at Davis.

Says Fitzgerald: "We're really just beginning to understand the interplay between brain structures, chemicals, and sheep sexual behavior. Hopefully, as we learn more, we'll find a quick and easy test to select better rams."—By **Julie Corliss,** formerly with ARS.

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Ceramic Microfilters Clean Up Brine

SCOTT BAUER

With microfilters, as much as 90 percent of the brine inside a meat processing plant can be made clean enough to reuse. Here, chemical engineer Marcus Hart checks clarity of filtered and unfiltered brinewater. (K4278-7)

Processors of holiday hams and spicy sausages may tomorrow rely on ceramic microfilters to clean thousands of gallons of salty water, or brine. The high-tech filters could extend the life of brine that processors use to quickly chill cured meats from the smokehouse.

Too, microfilters could offer a safe, nonchemical alternative to sterilizing brine with chlorine. Currently, chlorination is the method most widely used to sanitize brine so it will be clean enough to use more than once.

Foodmakers, consumers, and the environment should benefit, says Marcus R. Hart of the Western Regional Research Center, Albany, California. Microfilters could reduce costs of disposing of used brine. Today, meatpackers pass that cost on to consumers.

Processors use brine because the salt it contains keeps cold water (26°F) flowing when it would otherwise freeze.

With microfilters, as much as 90 percent of the brine can be made clean enough to reuse inside the packing plant, according to preliminary experiments by Hart and colleagues.

Microfiltration may help safeguard the environment by lessening the amount of brine that ends up in municipal wastewater treatment plants. Brine adds unwanted salt to the water supply. What's more, the salt kills helpful microorganisms that treatment plants rely on for cleanup chores.

> The tests might pave the way to future federal approval of microfiltration for sanitizing brine.

Hart works with ARS colleagues Lee-Shin Tsai, Keng C. Ng, Charles C. Huxsoll, and Peter F. Hanni at Albany. The team has experimented with a small, prototype microfiltration system both at their California laboratories and in Pennsylvania at Hatfield Quality Meats, Inc., a pork products company.

USDA's Food Safety and Inspection Service, responsible for the wholesomeness of meat and poultry products, is closely following the researchers' progress.

The tests might pave the way to future federal approval of microfiltration for sanitizing brine. Right now, however, the technique is still too slow to be economical. Hart has speeded it up by adjusting brine's acidity and pumping it through coarse filters to remove large, unwieldy particles before they reach—and clog— the microfilters. He's also added enzymes to the water to break down protein particles to a size microfilters can deal with.

Together, these tactics make the process up to 10 times faster. After more experiments, he'll try these ideas, and others, at the Hatfield plant.

The microfilters he uses are made of a porous ceramic pipe inside a slightly larger stainless steel housing. Used brine is pumped to the ceramic pipe. Some of it, instead of flowing straight out the other end, travels sideways, working its way through the microporous ceramic walls.

Bacteria, and all but the finest particles, can't pass through the walls. Instead, they accumulate in a concentrate of brine that needs further cleaning. The concentrate is left behind as the cleansed brine squeezes through the ceramic walls and eventually emerges in the narrow gap between the ceramic

SCOTT BAUER

Chemical engineer Marcus Hart assembles a microfiltration unit. (K4278-4) In experiments, used brinewater is pumped into the ceramic tubes (closeup at right, top) where it filters through porous walls into the stainless steel housing for reuse. (K4278-14)

SCOTT BAUER

pipe and the stainless steel housing. There, it can be piped away for reuse or, in this case, for retesting.

Meanwhile, the concentrate flows out the other end of the ceramic pipe. The concentrate can be sent for more passes through the filter until its volume becomes so small and so concentrated that it's too expensive to reclean further.

With proper maintenance, the hardworking filters can be reused repeatedly, though the research team hasn't yet determined how often the devices would need to be replaced. "They're costly, compared to other filters," says Hart, "so you want them to last a long time."

Ceramic microfilters aren't new—they've been around since the 1940's. But improved models like the one the Albany scientists are testing have been on the market for only about 10 years. The team is apparently the first to explore microfilters' potential to clean up packing plant brine.—By **Marcia Wood,** ARS.

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DALE MARSHALL

A reinforced vinyl hammock installed in a high-lift trailer breaks the fall of mechanically harvested carrots. As the trailer fills, corner straps stretch until the hammock rests on the trailer bottom. (K5065-2)

Hammocks Reduce Harvest Rough and Tumble

Dale Marshall is spending his days experimenting with hammocks. But he's not gearing up for retirement; he's trying to maintain the quality of harvested vegetables.

Carrots, cucumbers, onions, and potatoes are easily damaged during harvest—especially when the crops are dumped from a harvester into a high-lift trailer and then into a semi-trailer truck. In many cases, the produce may plummet up to 8 feet before it hits bottom. "The most damage occurs to the first 6 to 8 inches of the crop that hits the bare steel bottom of a trailer," says Marshall, an agricultural engineer in the ARS Fruit and Vegetable Harvesting Research Unit at East Lansing, Michigan.

He found that a simple piece of reinforced vinyl with its corners attached to the sides of the trailer with tarp straps will break the fall and reduce damage to the produce. The empty hammock sits 24 to 36 inches off the bottom of the trailer, so instead of dropping the full height of the trailer onto a rigid surface, the vegetables will fall just a few feet, onto a flexible surface.

Tests show that for the first 6 to 8 inches of carrots dumped into an empty steel trailer, the hammock reduces damage by two-thirds. Damage to the other three crops being evaluated—cucumbers, potatoes, and onions—is reduced by about 50 percent.

Farmers are paid less for damaged produce than for top-quality. With carrots, it amounts to a reduction of about $1 per high-lift load.

Marshall feels confident that the high-lift hammock would pay for its $350 to $400 cost in just 1 year, based on 30 loads per day during harvest. However, it would take up to 2 or 3 years to offset the cost of equipping semi-trailers with the hammock, because they are commonly filled and emptied only four or five times a week.

During tests last fall on Michigan farms, vegetable growers gave the hammocks high marks.

"These hammocks have a lot going for them," says Marshall. "They're basically inexpensive, easy to install and remove, and repairable."

Marshall is optimistic that the various hammock designs will be commercially available to vegetable growers in the near future.

Inspiration for the hammock came after a trip to Scandinavia in August 1991. Marshall learned of a similar system used in Holland, but thought it was too expensive. He contacted Orion Corporation of Sarasota, Florida, and has been working with the company to design a hammock that will provide the greatest damage reduction.—By **Marcie Gerrietts,** ARS.

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Science Update

Weevil giveaway: Extension agents can keep all the flowerhead weevils they find at an ARS field day next month in Kerrville, Texas. They'll later free the insects to battle musk thistle in their home counties. The thistle—a spiny pasture weed that can grow 7 feet tall—is common in central Texas and 25 other states. But each female weevil lays about 200 eggs in thistle flowerheads. Emerging larvae damage seeds, which won't sprout. Freed in Texas in 1987, the weevils lay low until 1991 when their populations bloomed and they damaged 50 to 90 percent of thistle flowerheads on test plots. The 5/8-inch brown insects, originally from the Mediterranean area, have been released in other states with good results. *Paul E. Boldt, Grassland Protection Research, Temple, Texas. Phone (817) 770-6530.*

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Loading up on carbohydrates can boost the endurance of marathoners and other hard-training athletes. But it doesn't pay off this way for men who exercise only moderately. A study of 18 men in their twenties and thirties compared their strength and endurance after 3 weeks of getting 62 percent of their calories as carbohydrates, and 3 weeks with 42 percent. None could pedal a stationary bike longer or had stronger leg or upper body muscles with the high-carbo regimen. *Joan M. Conway, Beltsville Human Nutrition Research Center, Beltsville, Maryland. Phone (301) 504-8977.*

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It may be a 1-day record for mass confusion in the insect world. More than 30,000 "confused sap beetles" scurried into a trap baited with a fake version of a feeding attractant chemical emitted by male beetles. The beetles spread fungi that damage corn, dates, figs, peaches, plums, pineapples, and other crops. Adding insecticide to traps could eliminate the need to spray it on crops. *Robert J. Bartelt, National Center for Agricultural Utilization Research, Peoria, Illinois. Phone (309) 685-4011.*

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A few years from now, plum lovers might be smacking their lips over several new varieties. Superior to other southeastern varieties in size, eating quality, and disease resistance, the new plums are being tested in 11 states. They were developed from a Japanese plum crossed with American species. *William R. Okie, Southeastern Fruit and Tree Nut Research Laboratory, Byron, Georgia. Phone (912) 956-5656.*

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An annual springtime ritual may mean less summertime forage. Each year, many farmers in the Southern Plains burn residues from the previous year's crop of grasses known as Old World bluestems. But a 4-year ARS study found the practice made forage yields drop an average of 16 percent. *William A. Berg, Range and Pasture Research, Woodward, Oklahoma. Phone (405) 256-7449.*

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A different nematode apparently is frustrated by a new ARS breeding line of soybeans. The new line, J87-233, could lead to commercial varieties resistant to race 2 and three other races of the soybean cyst nematode. Race 2 mainly infests soybeans in Virginia and North Carolina. *Lawrence D. Young, Nematology Research Laboratory, Jackson, Tennessee. Phone (901) 425-4741.*

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As a substitute for chemical controls for root-attacking reniform nematodes, cotton growers in Gulf Coast states might try alternating cotton with corn. The nematodes can slash cotton yields. But in greenhouse trials, scientists found 97 percent fewer of the pests on cotton roots when that crop was grown after corn. *Gary L. Windham, Corn Host Plant Resistance Research, Mississippi State, Mississippi. Phone (601) 325-2311.*

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Irrigated soybeans produced about triple the average U.S. yield when scientists gave the crop extra nitrogen and intensively managed the water table by pumping water into subsurface drainage tiles during drought periods. In a test, semidwarf soybean yields hit 100 bushels an acre. Unlike most of today's soybeans, semidwarf plants don't tend to lodge, or fall over. *Richard L. Cooper, Corn and Soybean Research, Wooster, Ohio. Phone (216) 263-3875.*

Correction

The list of 1890 Historically Black Land-Grant Institutions that appeared in *Agricultural Research,* February 1993 (page 10), omitted North Carolina A&T State University.

1866 - Lincoln University, Missouri
1871 - Alcorn University, Mississippi
1872 - South Carolina State University
1873 - University of Arkansas at Pine Bluff
1875 - Alabama A&M University
1876 - Prairie View A&M University, Texas
1880 - Southern University, Louisiana
1881 - Tuskegee University, Alabama
1882 - Virginia State University
1886 - Kentucky State University
1886 - University of Maryland–Eastern Shore
1887 - Florida A&M University
1891 - Delaware State College
1891 - North Carolina A&T State University
1895 - Fort Valley State College, Georgia
1897 - Langston University, Oklahoma
1912 - Tennessee State University

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